OPERATION CHEMISTRY CHALK IT UP

Beth Price
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The chemistry of calcium minerals highlights the properties that make the minerals useful in products and building.

INTRODUCTION

Calcium minerals are common and useful. In this activity, the calcium minerals of calcium carbonate (marble, limestone, and calcite) and calcium sulfate (gypsum, anhydrite) are compared, with sodium chloride (salt) as a reference.

OBJECTIVES

Students will be able to differentiate the calcium minerals of calcite and gypsum, and to list properties that make the minerals useful to civilization.

MATERIALS

- Source of calcium carbonate such as samples of calcite, calcium carbonate calcium supplement pills made of calcium carbonate, or antacid pill made of calcium carbonate.
- Source of calcium sulfate dihydrate (gypsum) such as gypsum crystals or gypsum board (wall board).
- Source of sodium chloride salt, preferably large crystals such as salt for melting ice or making ice cream.
- Clear plastic cups to use in testing
- Water (tap water should be fine)
- Stirring straws such as coffee stirrers
- Drinking straws to use as pipets
- Vinegar, white
- White blackboard chalk
- Marble chips

PROCEDURE (STUDENT DIRECTIONS)

1) Study the solubility of minerals in water
   a) Into three separate clear cups, place a sample of a few crystals of salt, calcium carbonate sample, and gypsum sample, respectively. In your notebook, describe each of the samples, noting differences and similarities.

   b) Without stirring, gently add some water, about 10mL, into each cup. Record observations of dissolution of each type of sample into your notebook. Look in at least two directions, from the top and from the side. Stir with the coffee stirrer to see if stirring makes a difference.
2) Study the solubility of minerals in a weak acid, vinegar.
   a) As above, test the solubility of each of the samples using about 10 mL white vinegar in place of the water. Record the observations in your notebook.
   b) What might the products of any reactions observed be?
3) Uses of the minerals
   a) On the basis of the relative solubilities of the minerals as observed in the tests, what uses might be possible?
      i) In what situations might high solubility be useful (table salt, for example) in a product?
      ii) In what situations might low solubility be useful (calcium carbonate, for example) in a product?
      iii) In what situations are the solubilities a problem for use of the minerals?
   b) What additional information is needed to suggest possible uses of the minerals?
4) Other properties that may be important to use in products. Consider ways these properties might be important, look up values or descriptions of the properties
   a) Hardness
   b) Cleavage
   c) Uniformity of large pieces of rock
5) Identify composition of blackboard chalk
   a) Use a test to determine the major component of chalk used on a blackboard, with the choice between calcite and gypsum.
6) How might these materials used in building situations change when exposed to weather—precipitation, air, freezing and thawing, and so on.
7) Lime, calcium oxide, is produced from calcite by heating the calcite and driving off carbon dioxide. Lime is the main component of cement and is also used as a soil conditioner and adjuster of pH.

EXTENSION

What other materials contain carbonate or sulfate ions?

Are such materials soluble?

Do they react with vinegar?

What are their uses?

How are they produced?

EVALUATION

Use the notebooks to evaluate observations and understandings.

Test with an unknown sample of $CaSO_4$ or $CaCO_3$

NOTES FOR TEACHERS

1) Chemical reactions
   a) Dissolution in water
      i) Calcite in water: $CaCO_3 \rightarrow Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$ (Occurs to a very small amount. Ksp = $[Ca^{2+}]\bullet[CO_3^{2-}] = 3.8 \times 10^{-9}$; where $[Ca^{2+}]$, for example, means the concentration of calcium ion in moles per liter.)
      ii) Salt in water: $NaCl \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ (Readily soluble, no solubility product)
      iii) Gypsum in water: $CaSO_4\bullet 2H_2O \rightarrow Ca^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2H_2O$ (Occurs to a small amount. Ksp = $[Ca^{2+}]\bullet[SO_4^{2-}] = 9.1 \times 10^{-6}$)
   b) Reaction with acid
      i) Vinegar is acetic acid, 5% aqueous solution: CH_3COOH The last H shown on the formula is the acid hydrogen: $CH_3COOH \rightarrow CH_3COO^{-}_{(aq)} + H^{+}_{(aq)}$
      (1) Acid dissociation constant Ka = $([CH_3COO^{-}]\bullet[H^{+}])/[CH_3COOH] = 1.5 \times 10^{-5}$
      ii) Calcite with acid: $CaCO_3 + 2H^{+}_{(aq)} \rightarrow Ca^{2+}_{(aq)} + CO_{2(g)} + H_2O$
   c) Production of lime: $CaCO_3 + \text{heat} \rightarrow CaO + CO_{2(g)}$
2) Minerals and compositions
   a) Table salt, often merely called salt: NaCl, sodium chloride
   b) Calcite, often when in a fine grained form, called chalk or limestone: $CaCO_3$
   c) Lime: CaO
   d) Gypsum: $CaSO_4\bullet 2H_2O$
   e) Anhydrite: $CaSO_4$
   f) Plaster of Paris or hemihydrates (not a mineral, produced from gypsum): $CaSO_4\bullet ½H_2O$

REFERENCES

Minerals, properties, chemical formulas, uses:
http://www.minerals.net/mineral/index.htm

Solubility product constants http://www.csudh.edu/oliver/chemdata/data-ksp.htm

Plaster of Paris http://en.wikipedia.org/wiki/Plaster

Acid dissociation constants
http://pages.towson.edu/debye/chem111/handouts/111_ka_table.html

Weathering of building materials:
http://www.buildingconservation.com/articles/atmospheric/atmospheric.htm

Examples of weathering of building materials included in a field trip of DC:
http://www.gswweb.org/oconnor-fieldtrip.pdf

Smithsonian classroom activity of weathering:
http://www.smithsonianeducation.org/educators/lesson_plans/buildingup/SIYC_BuildingUp_May2000.pdf

Other web references about calcium carbonate and gypsum:

http://scifun.chem.wisc.edu/CHEMWEEK/Lime/lime.html

http://www.bookrags.com/research/calcium-carbonate-woc/

http://www.mii.org/Minerals/photolime.html

http://www.mii.org/Minerals/photogyp.html